SIEMENS

MAMMOMAT 1000/3000

SP

Service Instructions

New AEC

Register 5
Print No.: SPB7-230.898.01.01.02
Replaces: n.a.
English
Doc. Gen. Date: 04.00

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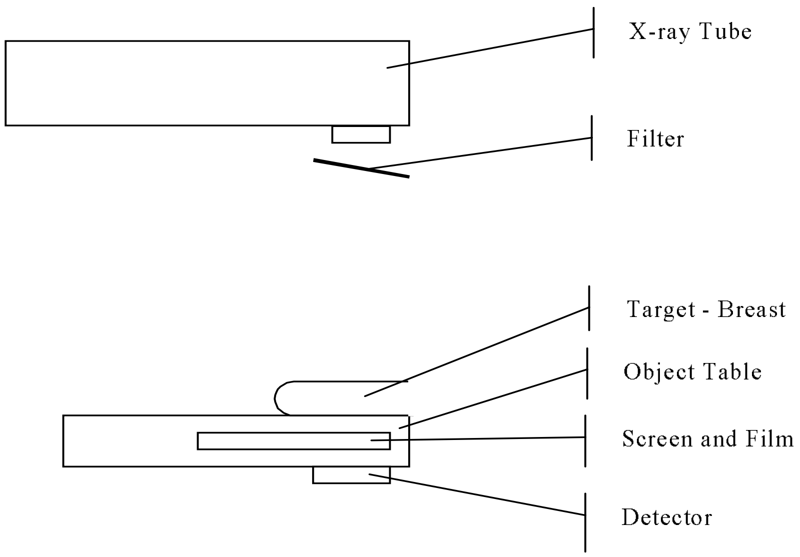
Overview

This document describes the control model of the AEC unit for M1000/3000. A view of the function of the Mammomat is given together with a summary of possible exposure settings, their effects and characteristics of Mammomat performance. The function of dose control is described together with an explanation of measurements done during the exposure, on which it is based.

Main function of the MAMMOMAT

Picture below gives a schematic view of the exposure system.



Schematic view of the Mammomat

The generator supplies a voltage across the x-ray tube. The resulting radiation is filtered before it reaches the target. Then it passes through an object table and reaches the fluorescent screen, which emits visible light giving the desired picture on the film. The part of the radiation, which is not attenuated in the screen, reaches finally the detector and results in a signal measured by the AEC unit. The main purpose of the AEC unit is to stop the exposure so that the resulting picture is given the desired average optical density based on current exposure settings and the measured signal from the detector.

Tube

When a voltage is applied across the x-ray tube, the electrons, hitting the anode, initiate radiation. The tube contains two different anode materials - molybdenum and tungsten - giving different kind of x-ray spectra. There are actually two different anodes for each mentioned material, used to give large and small focus for the x-ray beam. Small focus is used together with magnifying object tables. Large focus is used for all other object tables.

The operator is allowed to choose a desired tube voltage from a range between 23 and 35 kV with 1 kV resolution. The voltage influences the energy spectrum and gives the operator a control of how hard x-rays are used during the exposure. The current through the tube, which is directly proportional to the overall intensity of the beam, is a function of the chosen voltage, the maximum power setting and the maximum current limit.

Neither the energy spectrum of the beam nor it's intensity are constant during the exposure, due to raising and falling times for the voltage and the tube current. The voltage has typical raising times of app. 50 ms and the tube current 5 ms.

Filter

Different filtering is used to give the beam desired energy spectrum. For the molybdenum anode, two filter selections are possible: molybdenum and rhodium. For the tungsten anode, only rhodium is used as the filter material. This gives three possible anode/filter combinations - Mo/Mo, Mo/Rh and W/Rh - resulting in three main kinds of x-ray beam. Within each, a fine adjustment of the energy spectrum, i.e. the hardness of the beam, is possible by adjusting the voltage.

Object Table

There are totally 7 different kinds of object tables that can be used described in the table below.

Name	Type	Used beam focus	Size	Magnification
Grid 18 x 24	Grid	Large	18 x 24 cm	-
Grid 24 x 30	Grid	Large	24 x 30 cm	-
NoGrid 18 x 24	Grid-less	Large	18 x 24 cm	-
NoGrid 24 x 30	Grid-less	Large	24 x 30 cm	-
Mag 1.5	Magnification	Small	-	1.5
Mag 1.8	Magnification	Small	-	1.8
Biopsy table	Grid-less with biopsy unit	Large	-	-

According to their x-ray characteristics and use, the object tables are ordered into four groups: grid, grid-less, magnification and biopsy:

- Grid tables are used to take ordinary pictures and are equipped with a moving grid that reduces the amount of secondary radiation, i.e. scattered radiation from the target object.
- The grid-less tables are not equipped with a grid.
- The Magnification tables have enlarged distance between the object and the film, giving together with small focus of the radiation the desired magnification in the picture.
- The biopsy table, also called stereotactic table, is very similar to the grid-less tables. It is equipped with a biopsy unit that together with stereotactics is used to identify the 3D-position of the biopsy target within the breast and perform the biopsy. The pictures are smaller and can be taken from a direction not perpendicular to the object table. Angles of ± 10° are used.

Film and Screen

A considerable part of the radiation, which passes the target and possibly the grid of the object table, is attenuated in the fluorescent screen. The energy is than emitted as visible light and gives the desired picture on the film. The film is also sensitive to the x-rays, however the x-rays do not contribute to the picture significantly, compared to the visible light emitted by the screen.

Detector

After passing the filter, the breast, the object table with screen and film, the radiation finally reaches the detector. It is a semiconductor device that acts as a current source supporting a current proportional to the overall intensity of the attenuated radiation. The attenuation of the detector varies of course with the energy of the radiation, which makes the generated current dependent on the energy spectrum of the beam. The generated current is amplified and converted to a voltage level, which is the signal received from the detector by the AEC unit.

Measured Signal

The signal from the detector is amplified on the AEC board and than converted to pulses with a frequency proportional to the voltage level of the signal. The AEC unit contains a PLD (Programmable Logic Device), programmed to register the detector signal by counting the pulses that the signal is converted to.

Gain

Before every exposure, there is a possibility to alter the gain applied to the detector signal by the AEC board. Higher gain gives stronger signal to the V/F-converter, i.e. more pulses and better precision in the counters of the PLD. There is however an upper bound for the voltage level of the amplified signal - the V/F-converter functions for signals up to 10 V and all voltages above this limit does not contribute to larger frequency of out-coming pulses.

Dose Measuring

The dose is measured by counting the pulses from the V/F-converter during a time of interest. This dose measure is not comparable to any conventional dose units because it gives varying responses depending strongly on the energy spectrum of the radiation registered by the detector. However, for the same anode, filter, tube voltage, object table, screen and object, this dose measure is directly proportional to the dose received by the screen.

A logarithmic scale for the dose is also used. It is based on the usual definition of relative exposure and the unit exposure points (EP).

$$EP \quad 10\left(\log Dose_1 \quad \log Dose_0\right) \quad 10\,\log\,\frac{\mathrm{Dose}_1}{\mathrm{Dose}_0}$$

The used logarithmic scale is however absolute in the sense that 0 EP is defined to be equal to 100 counts:

$$Dose_{counts} \quad 100\; 10^{\frac{Dose_{EP}}{10}} \quad \text{i.e.} \quad Dose_{EP} \quad 10\,\log\,\frac{Dose_{counts}}{100}$$

Dose Rate Measuring

In order to measure the dose rate, the pulses are counted during a period of time and the resulting dose is then divided by the length of the time period. The resulting dose rate is an average over the chosen time interval.

Time Dependency

Due to the raising and falling times of the tube voltage and current, the detector signal is also time dependent and has typical raising times of 50 ms.

Two Wings

The Mammomat can have one or two wings using separate detectors.

User Choices

The following table summarises possible user choices affecting the exposure:

User choice	Range	Change consequence
Anode/ filter	Mo/Mo, Mo/Rh, W/Rh	Rough change of spectral properties of the beam, possibly affecting power settings and automatic choice of tube current.
Tube voltage	23 - 35 kV	Fine change of spectral properties of the beam, possibly affecting power settings and automatic choice of tube current.
Speed	H or D	Choice between two sets of parameters for two different film/ screen-combinations.
Density correction	-24/8 to + 24/8 EP	Relative adjustment of exposure length, 0 = nominal AEC exposure.
Object table	One of 7	See section Object Table
Wing	1 or 2	Different detectors in both wings.

Exposure control

The control model for the AEC-unit is typically subdivided into two parts. First part handles the control of a single exposure with one set of exposure settings such as kV, anode/filter etc. It is based on the knowledge of these parameters before the start and measurements done during the exposure. Second part puts the control model for one exposure into a systematic approach to all possible exposure settings for the Mammomat. It explains how the entire set of control parameters for the AEC-unit is build up in order to cover all possible combinations of kV, object tables, anode/filter choices and up to 2 film/screen combinations.

Control of One Exposure

Before start of exposure, the AEC-unit is only aware of exposure settings chosen by the operator and has no knowledge of thickness or density of the actual breast. This implies a two step approach to control of the entire exposure. First step is done before the exposure start and contains calculation of an initial dose that will be executed before the AEC will decide what to do next. During the execution of the initial dose, the unit measures the dose rate and uses it to calculate a correction dose that has to be executed before the exposure stops. When the AEC-unit has registered a total dose being equal to the sum of the initial dose and the correction dose, it will stop the exposure.

Initial Dose

The initial dose is chosen in EP. It consists of an estimated dose, a sensitivity, a sensitivity correction and a density correction:

$$Dose_{initial,EP} = Dose_{estimated,EP} + S_{,EP} + Sc_{,EP} + Dc_{,EP}$$

where:

$Dose_{estimated,EP}$ - the estimated dose, a value specifically chosen for the used film/screen combination, anode/filter combination, object table group and tube voltage.

$S,_{EP}$ - the sensitivity, a value controlling an overall level of target optical density for all AEC-exposures.

$SC,_{EP}$ - the sensitivity correction, chosen as a part of the calibration of specific equipment (Mammomat, object tables).

$DC,_{EP}$ - the density correction, a value that is chosen by the operator for each exposure.

The estimated dose is usually chosen, so it will give an OD = 1,5 for a 5 mm thick PMMA-phantom.

Dose Correction

In order to measure the dose rate with the detector, the following procedure is used. The initial dose is subdivided into a 60%-part and a 40%-part. Both parts are handled in the AEC-unit by two separate counters, implemented in the PLD. At the exposure start, the 60% counter starts counting down at the rate of pulses from the V/F-converter that handles the amplified signal from the detector. During counting down the 60% of the initial dose, time is measured by a time monitor. When the 60% counter has reached 0, the time is read and used together with the actual value of 60 % of the initial dose as an average dose rate:

$$Dr_{60\%} \quad \frac{0{,}6 \ \ Dose_{initial,counts}}{Time\left(0{,}6 \ \ Dose_{initial,counts}\right)}$$

where

$Time\left(0{,}6 \ \ Dose_{initial,counts}\right)$ - time as a function of 60 % of initial dose in counts.

At the same time, the 40% counter is enabled and continues monitoring of the dose. During execution of the remaining part of the initial dose, a calculation of the correction dose has to be done. The measured dose rate is compared with a decreasing sequence of dose rates, forming a so-called correction table. The index of each dose rate is a correction dose in 1/16 EP needed for a target giving such a dose rate, in order to give the desired OD on the film. When the first dose rate, being equal to or lower than the measured, is found in the sequence, the corresponding index is used as the correction dose. This gives the total dose of:

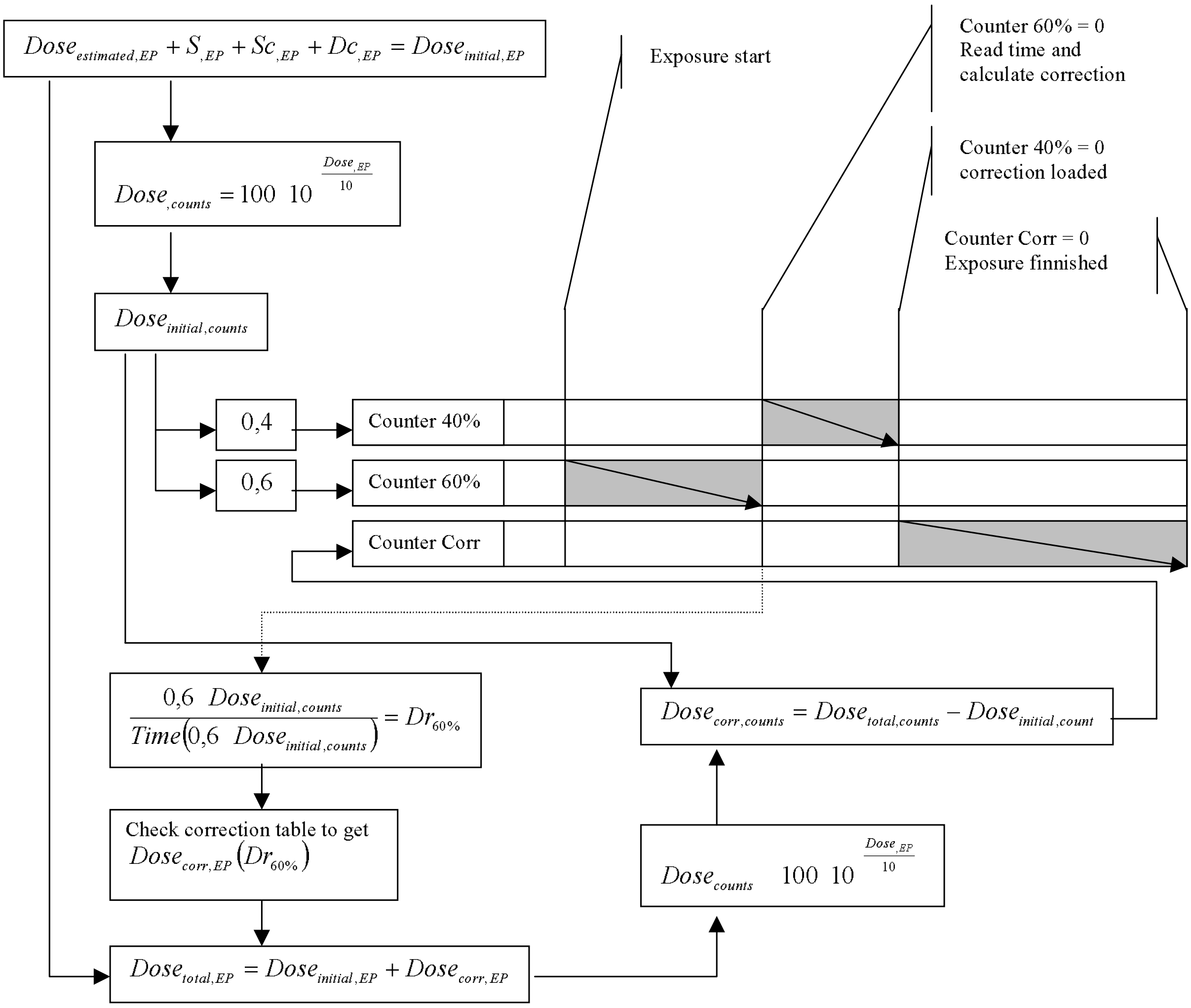
$$Dose_{total,EP} = Dose_{initial,EP} + Dose_{corr,EP}\left(Dr_{60\%}\right)$$

In order to receive the dose correction in counts, which is needed for initialising the third and last dose counter in the PLD of the AEC unit, the following formula is used:

$$Dose_{corr,counts} = Dose_{total,counts} - Dose_{initial,counts}$$

where the total dose and the initial dose are translated from EP to counts.

When the 40 % counter reaches 0, the correction counter initialised with the correction dose is enabled. When the correction dose is executed as well, the AEC-unit stops the exposure. The entire picture of dose calculation and execution is given in the figure below.



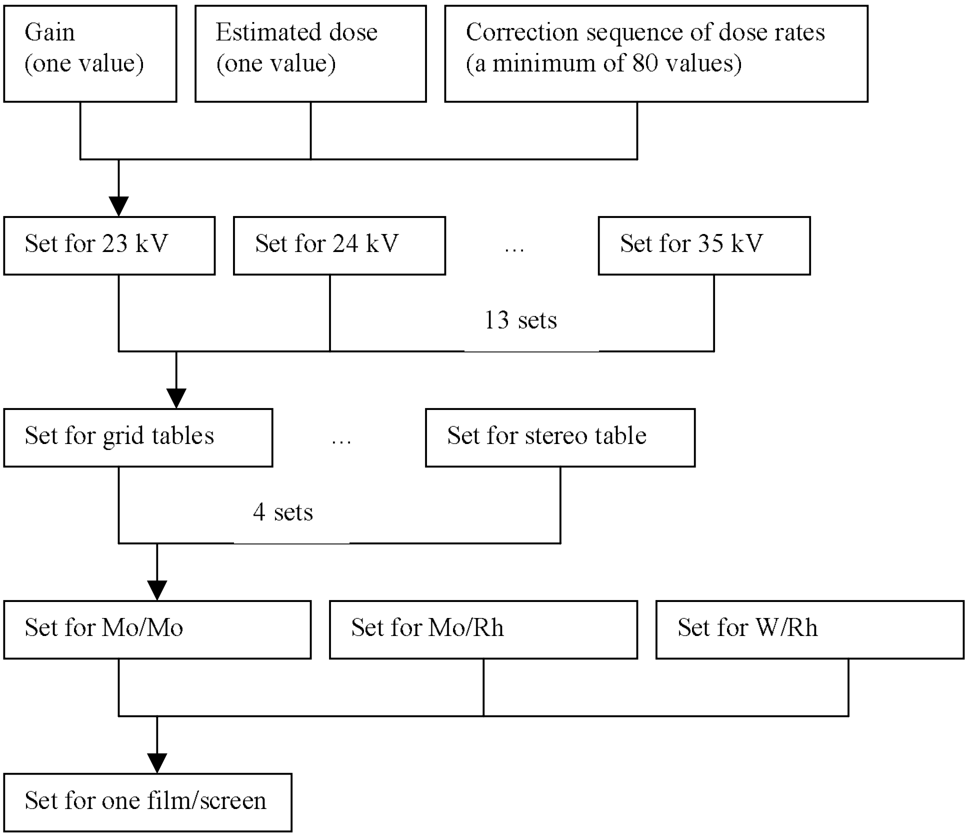
Dose calculation and execution in the AEC-unit

Entire Set of Control Parameters

The entire set of control parameters consists of three differently used parts. First part contains parameters that are chosen specifically for a film/screen-combination at laboratory by series of tests. These are called correction tables. Second part is sensitivity correction, used to calibrate a specific Mammomat. Third part is sensitivity, used to adjust the target OD for a specific Mammomat and one film/screen-combination (i.e. one speed) to the level requested by the customer.

Correction Tables

Correction tables contains gain values, estimated doses and correction values. These are structured in the following way:



- kV-set: one gain value, one estimated dose and a minimum of 80 dose rates forming the correction sequence, define the set of parameters used for specific tube voltage, object table group, anode/filter and speed.
- Table-group-set: 13 kV-sets defining the set of parameters for all tube voltages, one object table group, anode/filter and speed.
- Anode/Filter-set: 4 table-group-sets defining the set of parameters for all voltages, all object table groups, one anode/filter and speed.
- Film/screen-set: 3 Anode/Filter-sets defining the set of parameters for all user choices within one speed i.e. one film/screen-combination.

Because the Mammomat gives the user a possibility to choose between two different speeds, it can be equipped with two film/screen sets of parameters - one for each speed, H and D.

Sensitivity Correction

The sensitivity correction is possible to choose differently for all 7 object tables, 3 anode/ filter- combinations and 2 speeds. This makes totally 42 possible values, adjustable in 1/8 EP-steps.

Sensitivity

One sensitivity setting is allowed for each speed, H and D, which gives totally 2 sensitivities, adjustable in 1/8 EP-steps.

ERROR messages of the new AEC Er 4xx are described in the document "service program" from SW 4.0.

NOTICE	**The error messages Er 419 - Er 422 are internal errors. They do not interfer with an exposure and are not shown on the control panel.**

NOTICE	**Please report this errors immediately in accordance with the established processes.**

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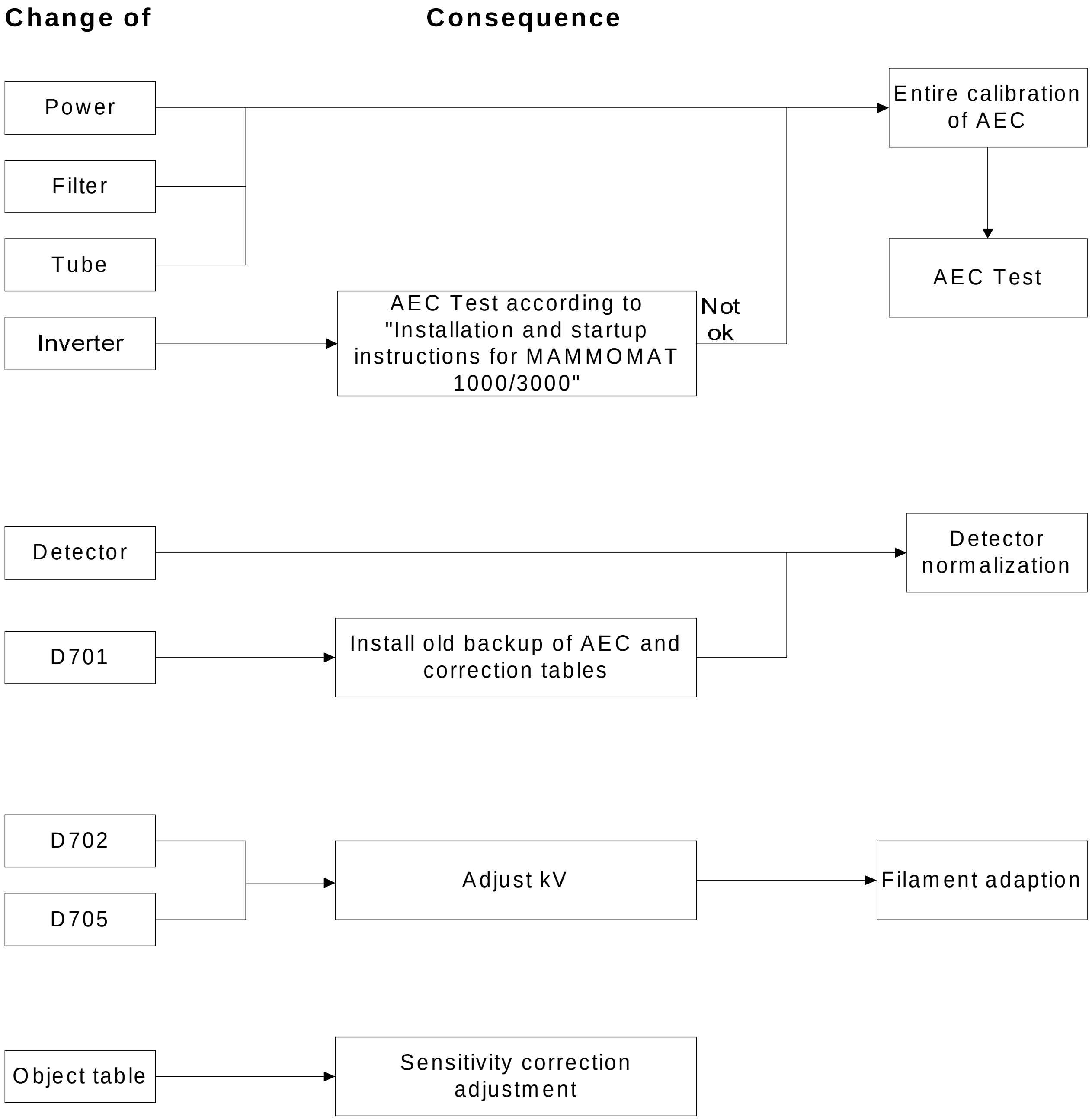
Action list for MAMMOMAT 1000/ 3000 with new AEC



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Measuring points on AEC board D701

TX	Communication from D701
RX	Bus communication
KVA_EXP_DONE	Indicates end of normal exposure
KVA_ABORT_EXP	Indicates exposure aborted by CPU on D701
0VD	-
0VA	-
VCC	5 V
D15V	15 V for logic
P15V	+ 15 V
N15V	-15 V
VOSCTL 1	Signal for control of offset compensation
SEL_RDL	Detector signal
A3_RDL	Amplified detector signal
A4_RDL	Amplified detector signal compensated for offset
AD_RDL	V/F converter output signal
FRDL	V/F converter output pulses
OFS_RDL	Offset compensation signal
X1	For factory test only
X2	For factory test only

Switches on AEC board D701

S1	For factory test only, set to zero

Jumpers on AEC board D701

X114	1 - 2 Normal / 2 - 3 No dose monitoring
J1	Forces offset compensation mode
J2	Forces measuring mode
J3	Generates an offset test signal

LEDs on AEC board D701

Processor (status)	Gain	PLD (detected error)	PLD (configuration status)
4 LEDs	3 LEDs	4 LEDs	1 LED

Processor LEDs

x	x	x	x	CPU not Running
	x	x	x	RAM Check
		x	x	EPROM Check
(			x	EPROM Check finished)
	x	x		Flash check
x			x	Ready

	x			RAM Error
	x			EPROM Error

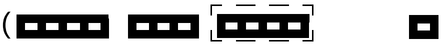
Gain LEDs

			$2^0 = 1$
x			$2^1 = 2$
	x		$2^2 = 4$
x	x		$2^3 = 8$
		x	$2^4 = 16$
x		x	$2^5 = 32$
	x	x	$2^6 = 64$
x	x	x	$2^7 = 128$

NOTICE	The gain displayed corresponses to the total gain, which is a function of the correction table gain (SW controlled) and the D701 gain (HW controlled).

PLD LED ()

If PLD is correctly configured and running, the LED is toggled with period of 1 sec.

PLD LEDs ()

If an error is detected by the PLD an 8-bit code is displayed on the 4 LED’s in a sequence as follows:

1. Initially the 4 LSB (least significant bits) of the error code are displayed during 1 second.
2. Then the 4 MSB (most significant bits) of the error code are displayed during 1 second.

To indicate that the entire error code has been displayed, each of the four LED’s are turned on one at time.
The sequence described above will be repeated until reset of the PLD.
An error code detected by the PLD can also be found with the Service PC program by entering the menu <Normal mode> <AEC data>.

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Check the AEC according to "Installation and start-up instructions" for MAMMOMAT 1000/ 3000

If AEC tests fails, check that:

- correct plexi has been used and positioning of plexi is correct and that used kV-setting is correct.
- used film/ screen combination is correct (reference cassette shall be used).
- correction for variations in film developing process has been correctly performed.

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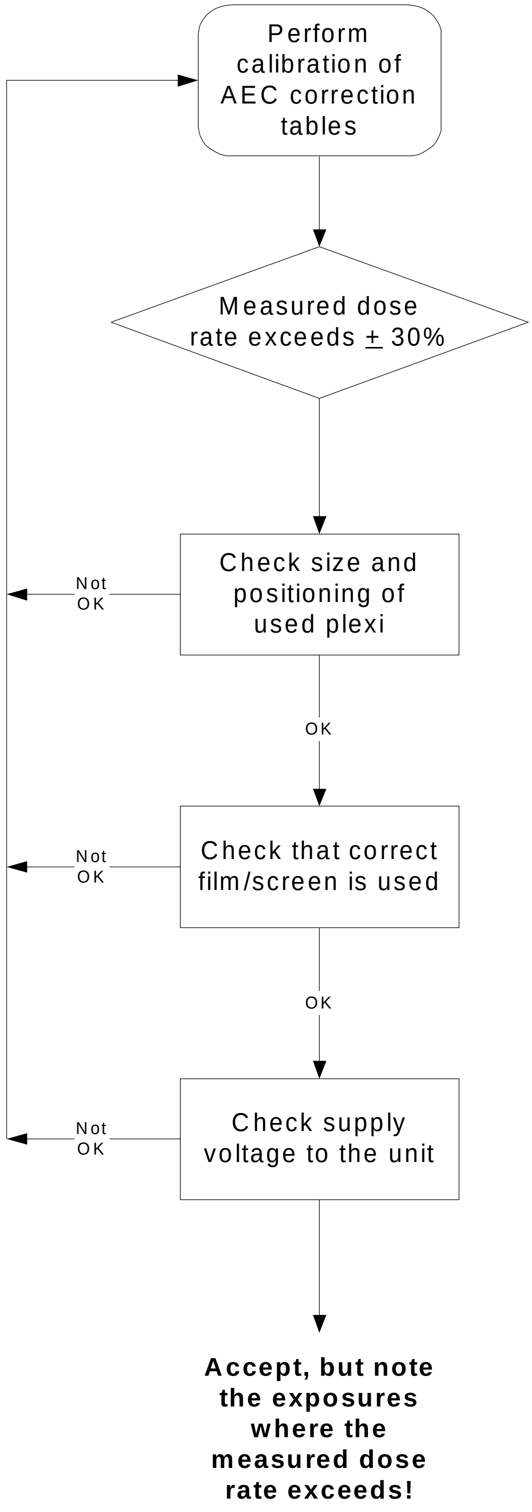
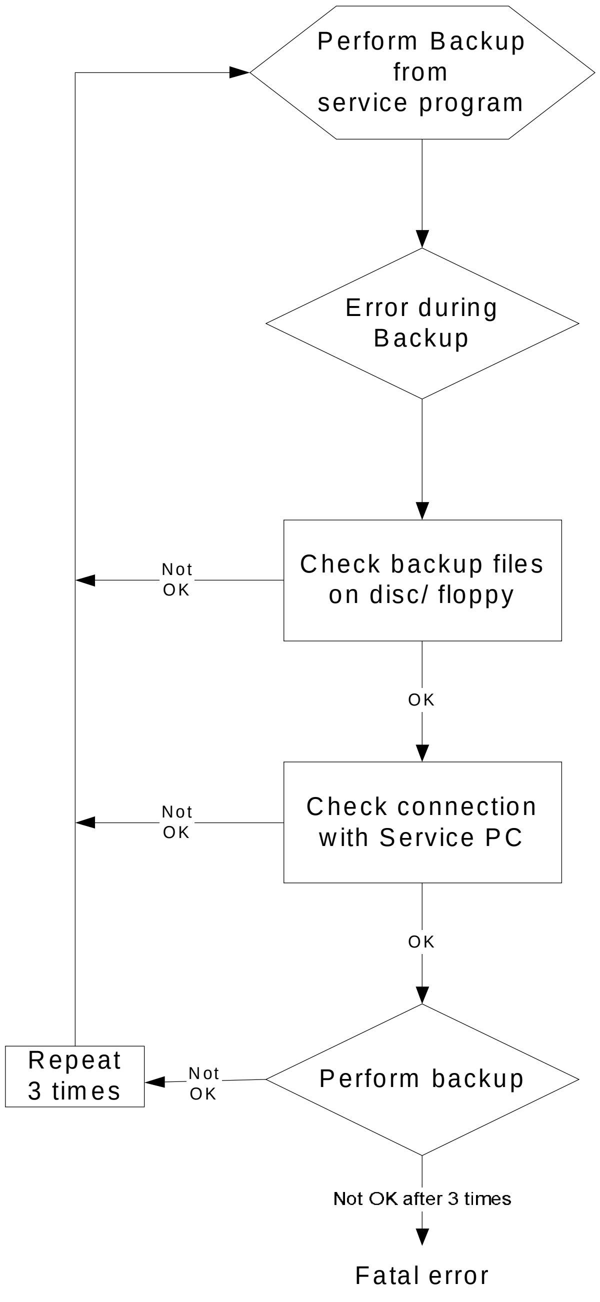
AEC Correction tables

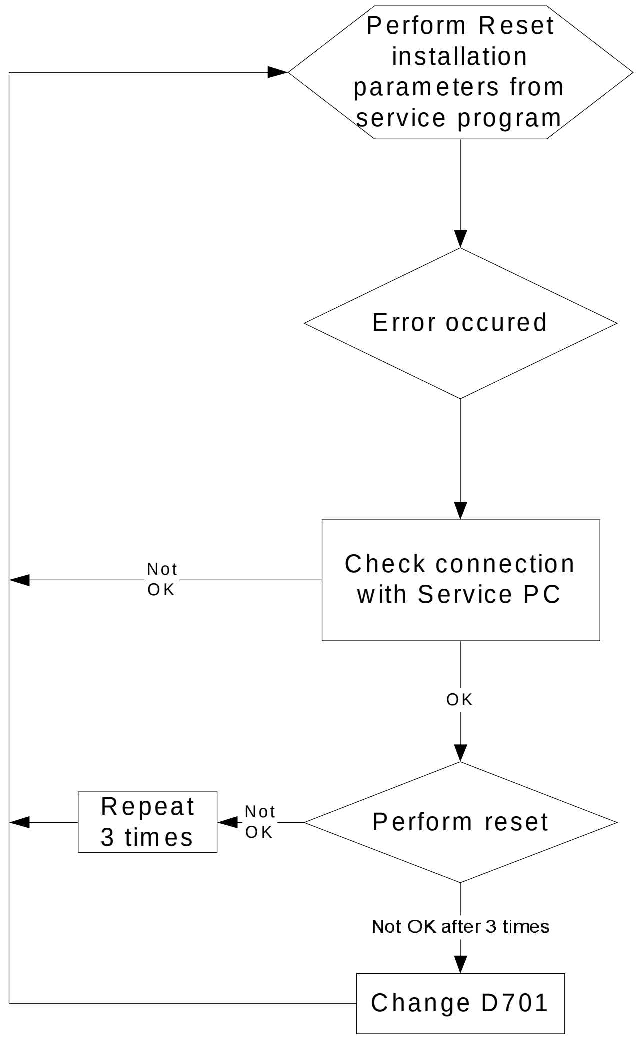
Measured dose rate exceeds ± 30%



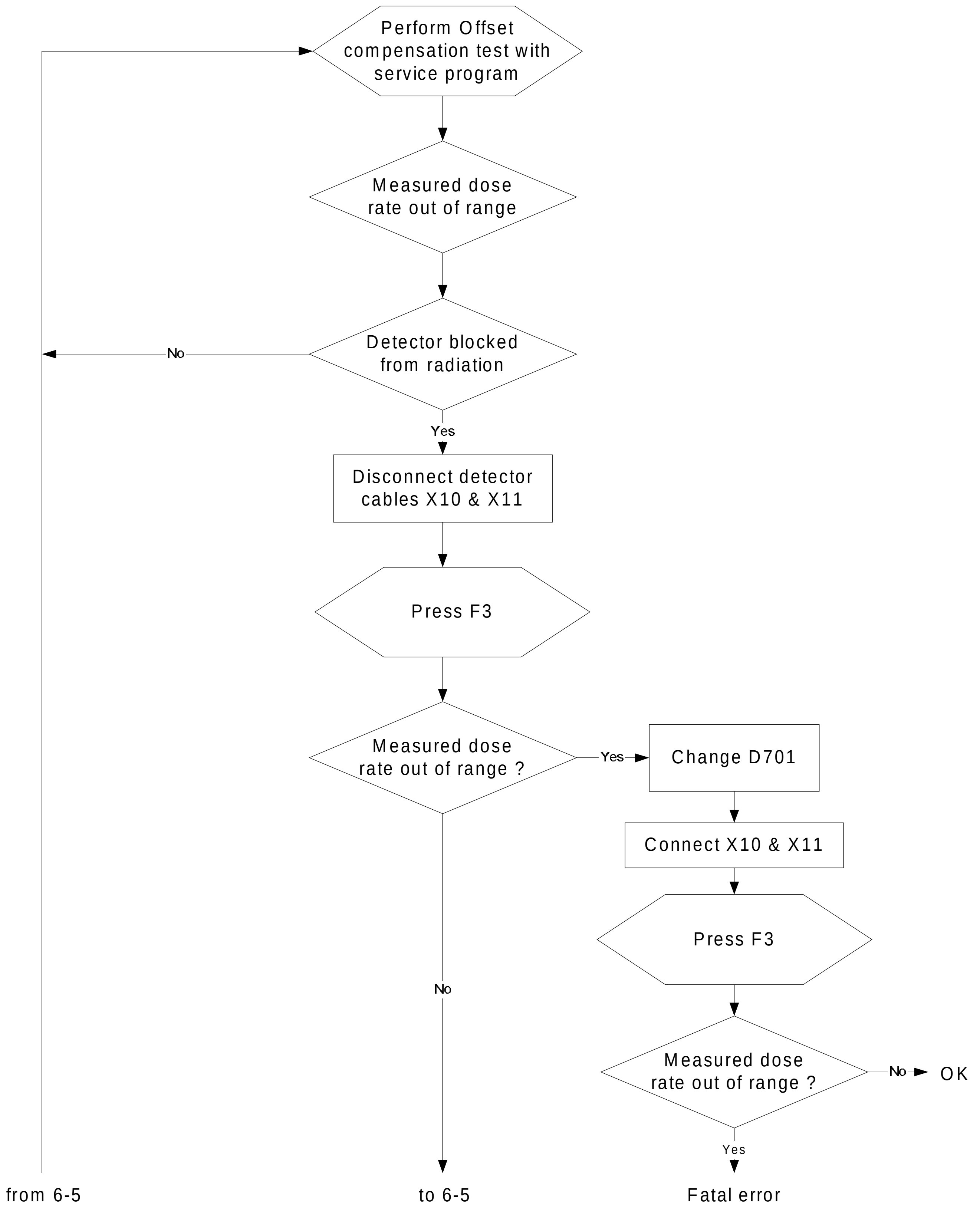
Error during backup from disc/ floppy

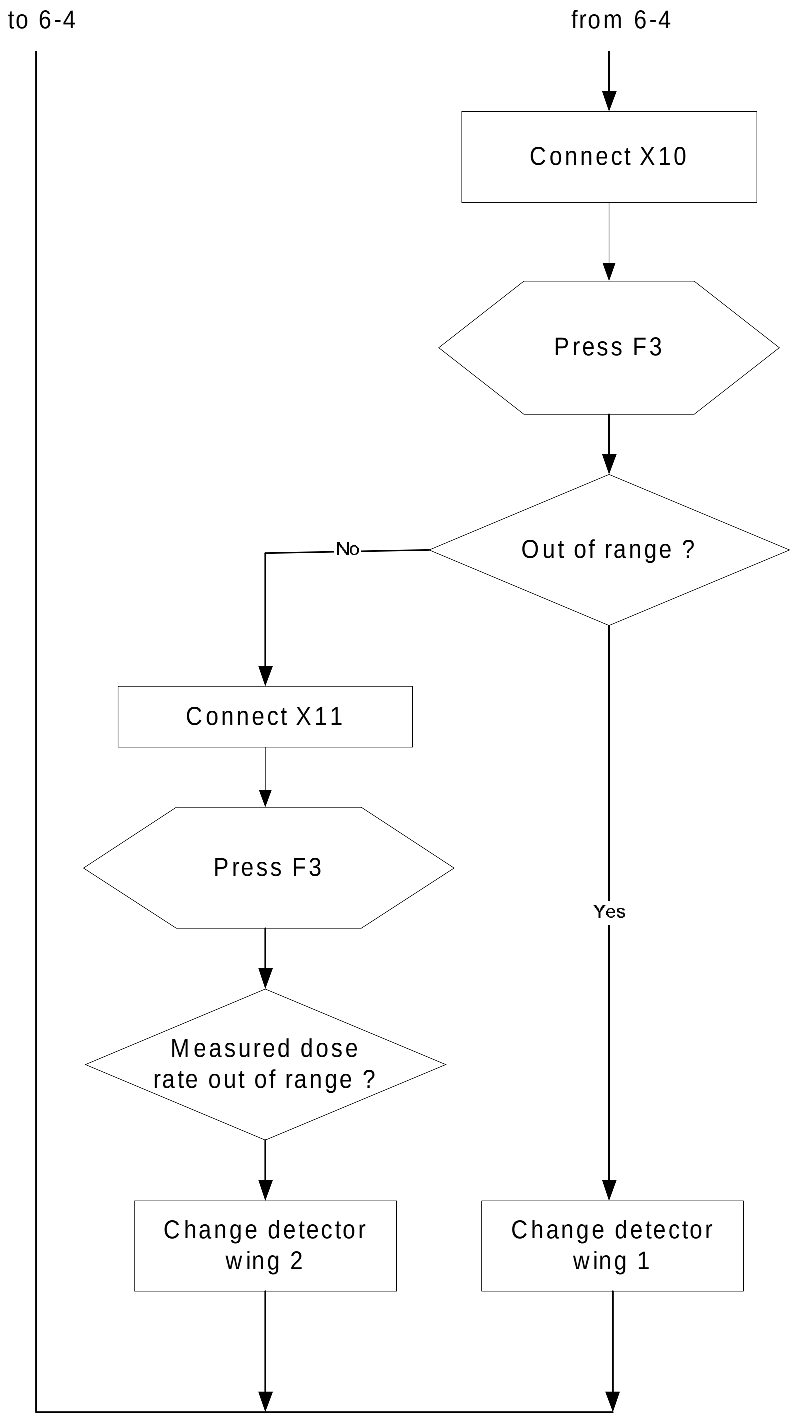


Error during reset of installation parameters



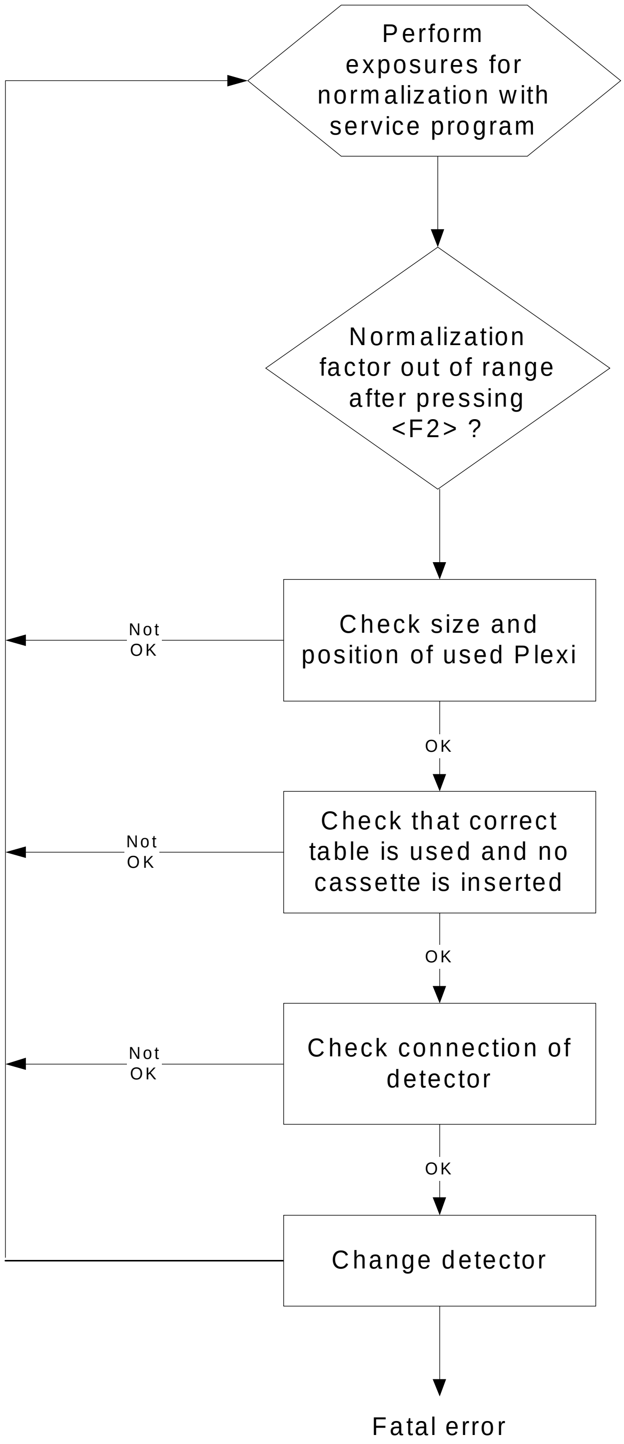
Errors during offset compensation test




to 6-4
from 6-4
Connect X10
Press F3
Out of range ?
No
Connect X11
Press F3
Yes
Measured dose rate out of range ?
Change detector wing 2
Change detector wing 1

Detector Normalization

Normalization factor out of range



Miscellaneous

Communication Errors with Service PC

- Check if the PC is equipped with an IR transmitter and disable it.

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